Hexcel Research
Reference: 6065

November 17, 1964

Picatinny Arsenal
Dover, New Jersey

Attention: Procurement and Production Directorate
SMUPA - PBI

Subject: Contract No. DA-04-200-AMC-477 (A)
Development and Evaluation of a Lightweight
Aluminum Honeycomb Case
Monthly Progress Report No. 9

Gentlemen:

Enclosed is the report describing the work done on the subject contract during the months of September and October, 1964. The report was prepared by the Advanced Structures Group, Research Division, Hexcel Products Inc., Berkeley 10, California.

Included as attachments are (1) Statement of Man Hours Expended - September and October, 1964, (2) Schedule showing Current Progress - September and October, 1964, and (3) Schedule showing Program of Ensuing Activities - November and December, 1964.

Yours very truly,

E. C. Vicars
Research Director

ECV:skw

Attachments (3)

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CONTRACT NO. DA-04-200-AMC-477(A)

REPORT OF PROGRESS

SEPTEMBER AND OCTOBER, 1964

Cases 9 and 10 were fabricated and tested during the months of September and October, 1964. A summary of design changes and test results is given below.

Design Modifications

1. Case HXL-9-477: The amount of the energy absorption core was increased from 17" to 27-1/2" along the length of the case. In addition, 16 longitudinal slots were cut out of the core as shown in Figures 1 and 3.

   As part of the work that constituted Case 9, several rings of honeycomb were manufactured and tested for the purpose of determining the dimensions of slots that would give the best impact response for the entire case. These are shown in Figure 3.

2. Case HXL-10-477: The size of the slots in the energy absorption core was increased slightly over that of Case 9, as shown in Figure 2.

In all other respects, Cases 9 and 10 were identical with Case HXL-8-477.

Movies

Motion pictures were taken to provide a visual record of the environmental tests performed on Cases 8 and 10. The record includes pictures of the equipment used and the conduct of the following tests:

1. Case HXL-8-477
   a) temperature shock
   b) transportation vibration
2. Case HXL-10-477
   a) hydrostatic pressure
   b) impact

High speed (200 frames/second) pictures were taken of the impact tests to better illustrate the crashing action of the honeycomb core.

Test Results

1. Hydrostatic Pressure Test:

The pressure test was not performed on Case 9. Case 10 was twice subjected to an external pressure for a duration of five (5) minutes. At the completion of pressure cycles, the case was filled with approximately one (1) foot of water. By visual inspection, it was determined that the leaks were caused by poor sealing at the electrical connector and the locking device on the front cap. Design changes are being made on Case 11 to correct these deficiencies.

2. Impact Tests - General Comments:

The results of tests on Cases 6, 6a, 7 and 8 indicated the need for design changes to reduce the payload response to impact from side drops. In addition, the problem of payload vibration within the case structure has made it necessary to clarify the methods being used for data acquisition and analysis.

When the payload is decelerated during impact, the total acceleration consists of the sum of the response to the forcing function and the transient free vibration. Since the payload-case system is continuous (as opposed to a lumped parameter system), the free vibration component is composed of an infinite sequence of mode shapes and frequencies. This means that the total acceleration experienced by the payload will be different at every point even though the response to the forcing function is approximately the same everywhere.

To cope with this situation, the project engineers at Picatinny Arsenal and Hexcel have agreed that the following criteria will be used in evaluating the case design:

1. The acceleration of the payload will be measured at the mounting ring and at the free end of the payload (see Figure 4).

2. The case design will be considered satisfactory with regard to impact response if the faired value of the acceleration-time

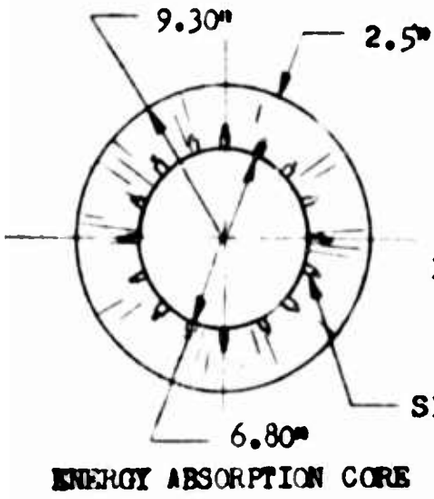
relationship, measured at the mounting ring, is less than the contract specification (27 g's laterally, 40 g's axially).

For side drops, the average peak value of the faired a-t curve (measured at the mounting ring) on Cases 6 through 8 was 33.3 g's. In an effort to reduce this value to 27 g's, impact tests were performed on several rings of honeycomb core as shown in Figure 3. Tests on ring segments are simpler to perform and yield more accurate measurements than tests on the entire case. The results of tests on the rings led to the conclusion that the acceleration response of the payload could be decreased by increasing the amount of core along the length of the cylinder providing there was a means to reduce the crushing strength of the honeycomb at large deflections. Drop tests on Cases 9 and 10 demonstrated that this conclusion was correct.

The reasoning behind this is as follows. The best energy absorber (for this application) would be one that absorbs energy at a constant rate. This requires a honeycomb configuration that crushes with a constant force, a condition that is difficult to achieve with the increasing area that results from crushing a cylindrically shaped object.

Without modification, i.e. no slots, honeycomb of this configuration yields a force-deflection curve where the force increases almost linearly with deflection until the total kinetic energy is absorbed. To approach the ideal more closely, an additional 10 lineal inches of honeycomb were added to the case. The additional honeycomb increased

the total crushing force at small deflections, while the slots weaken the core, resulting in a more nearly constant force at larger deflections. These relations are shown below in Figures a, b and c.



ENERGY ABSORPTION CORE

FIGURE a.

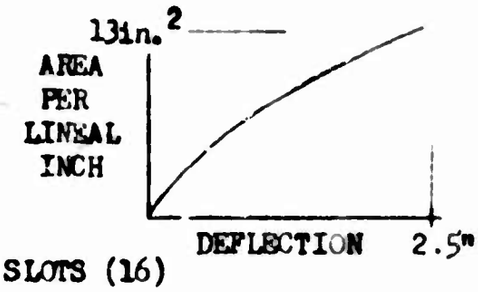


FIGURE b.

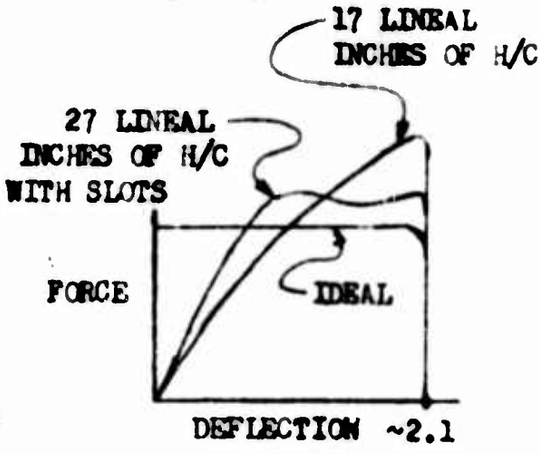


FIGURE c.

Case HXL-9-47Y:

Typical results for Case 9 are shown in Figures 5, 6, 7, 8 and 9. For all drop tests, the accelerometers were mounted as shown on Figure 4. The acceleration response of the honeycomb ring shown in Figure 5 came closer to yielding a constant force-deflection relationship than any of the other rings tested. The unit loading of this ring was the equivalent of 27-1/2 inches of honeycomb on the full-length case.

Figure 6 shows the acceleration response for Case 9, drop 3 (9-3). Case 9 was tested without skin and end caps so that the payload response could be more easily correlated with the impact tests on the honeycomb rings.

Figure 7 shows the acceleration, velocity and displacement responses for both the fixed and free ends of the payload during drop 9-3. These were obtained by double integration of the faired acceleration-time curve. The force-deflection relationship at each end of the payload is obtained by eliminating the parameter time from the a-t relationship and the displacement-time relationship. The force-deflection relationships for 9-3 are shown on Figure 8.

Figure 9 is a comparison of various force-deflection relationships. The curve labeled "Parson's Ring" was supposed to give the same response as the "Best Ring" (from Figure 5). The difference in response was attributed to manufacturing variations in the shape of the slots.

Also shown are drops 1 and 3 for Case 9. Complete results of the drop tests on Case 9 are shown in Table 1. The average peak value of faired a-t curve, measured at the mounting ring, was 26.0 g's for 4 drops.

There were no end drops or edge drops performed on Case 9.

Case NXL-10-477:

The accelerometers were mounted as shown on Figure 4.

Side Drops: The average peak value (for 3 drops) of the faired a-t curve was 28.4 g's at the mounting ring and 29.4 g's at the free end of the payload.

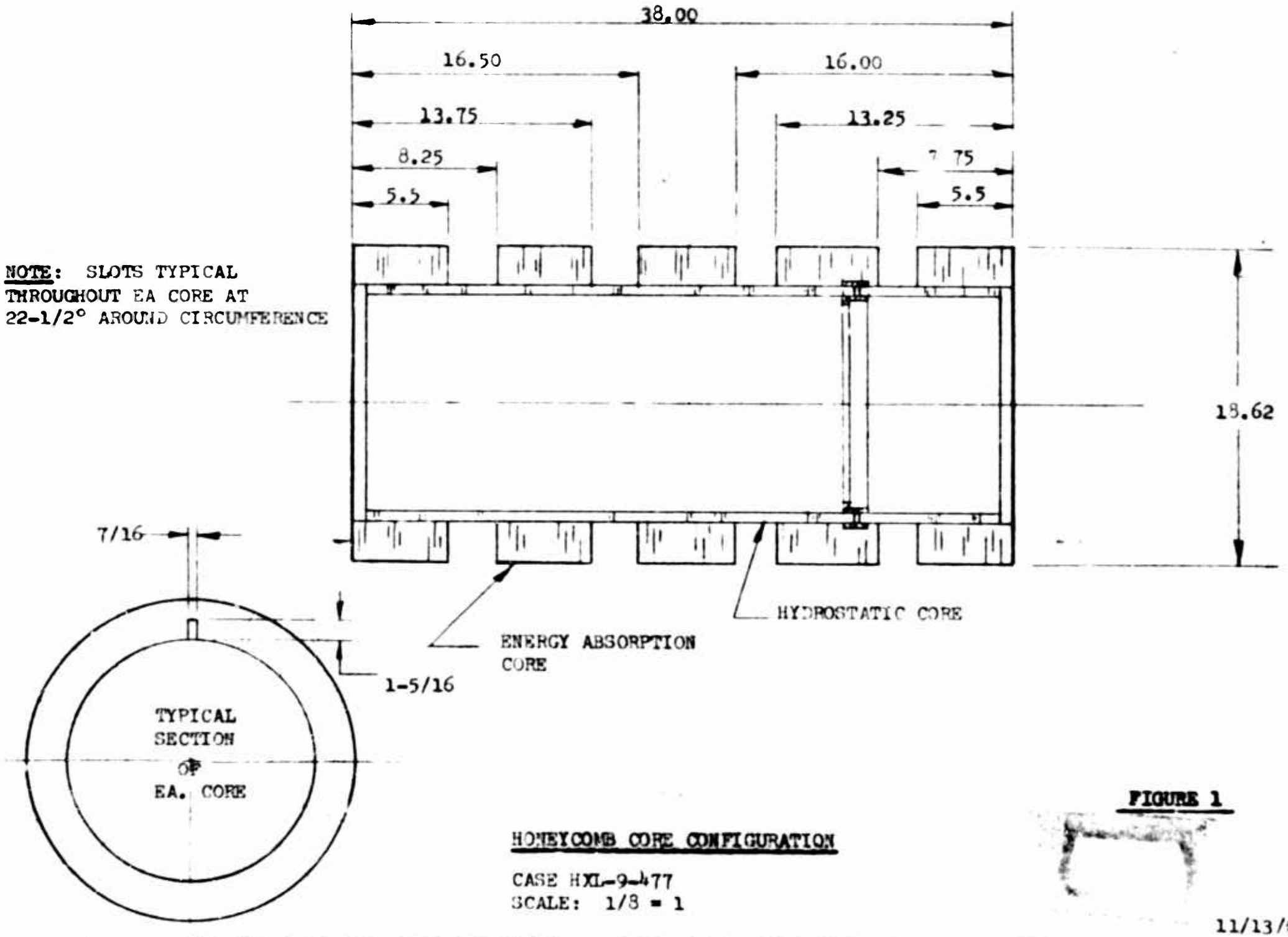
End Drops: The peak value of the faired a-t curve was 24.2 g's, average for 2 drops.

Edge Drops: One edge drop was performed, yielding a maximum value of 16.5 g's on faired a-t curve.

The results of all drops are shown on Table 2.

Attachments:

1. Statement of man hours expended during September and October, 1964.
2. Program of activities during September and October, 1964.
3. Projected schedule of activities for November and December, 1964.



NOTE: SLOTS TYPICAL THROUGHOUT EA CORE AT 22-1/2° AROUND CIRCUMFERENCE

FIGURE 1

HONEYCOMB CORE CONFIGURATION

CASE HXL-9-477
SCALE: 1/8 = 1

11/13/64 F.P.

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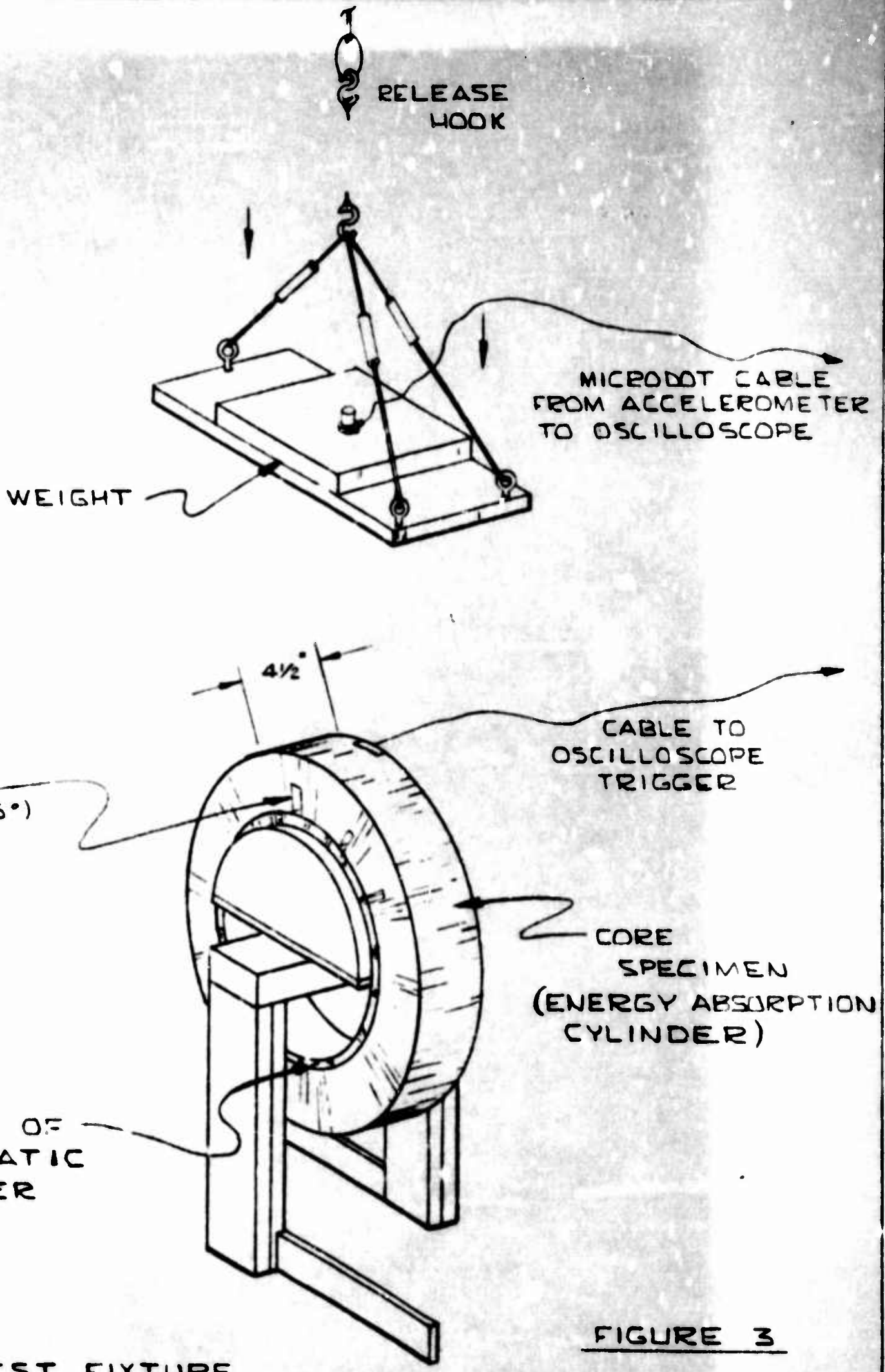

FIGURE 3

DROP TEST FIXTURE
NOT TO SCALE

PROJECT 6065 10/13/64

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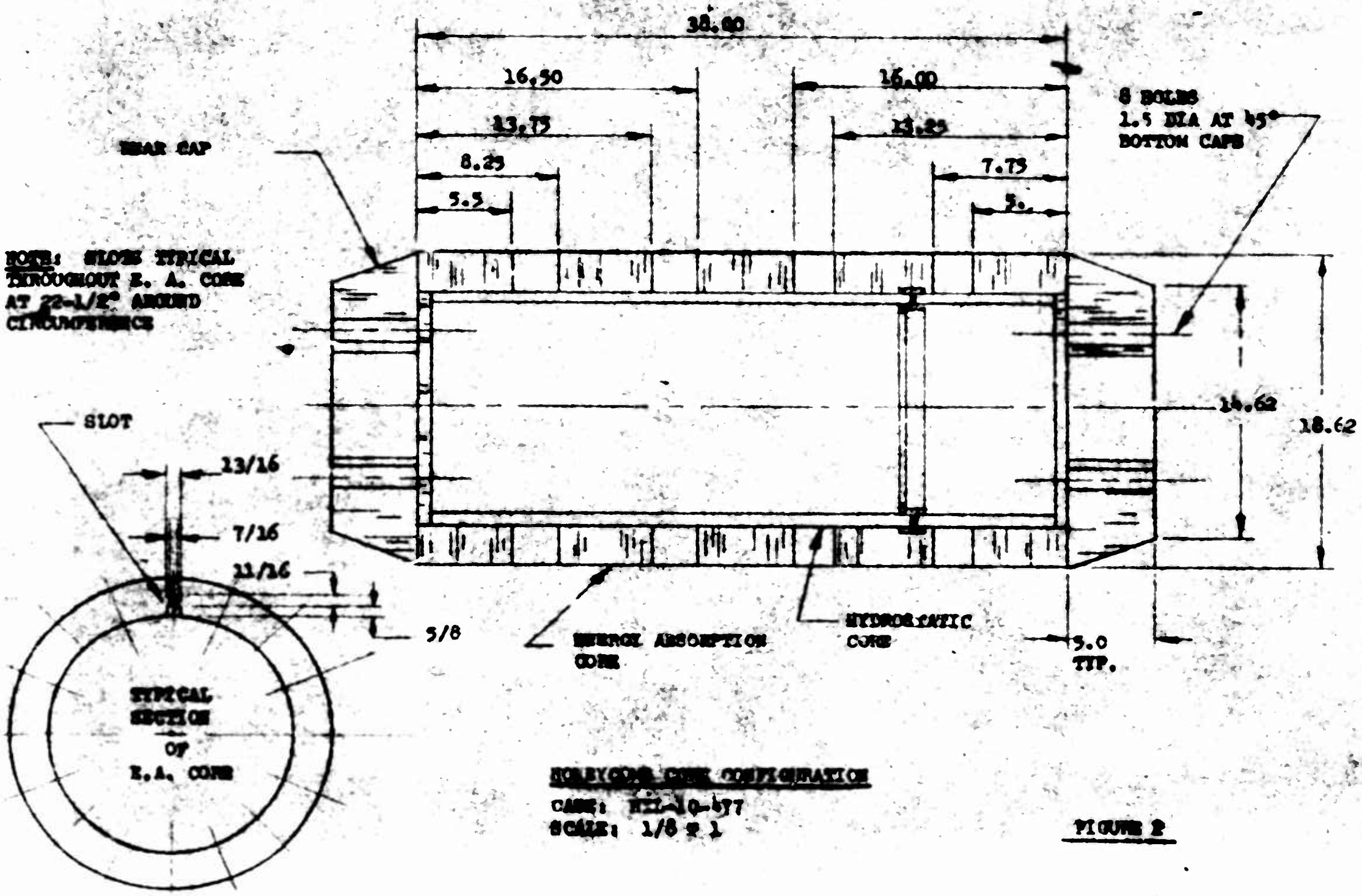

HONEYCOMB CORE CONFIGURATION

CASE: [illegible]-677

SCALE: 1/8 = 1

FIGURE 2

11/13/64 F.P.

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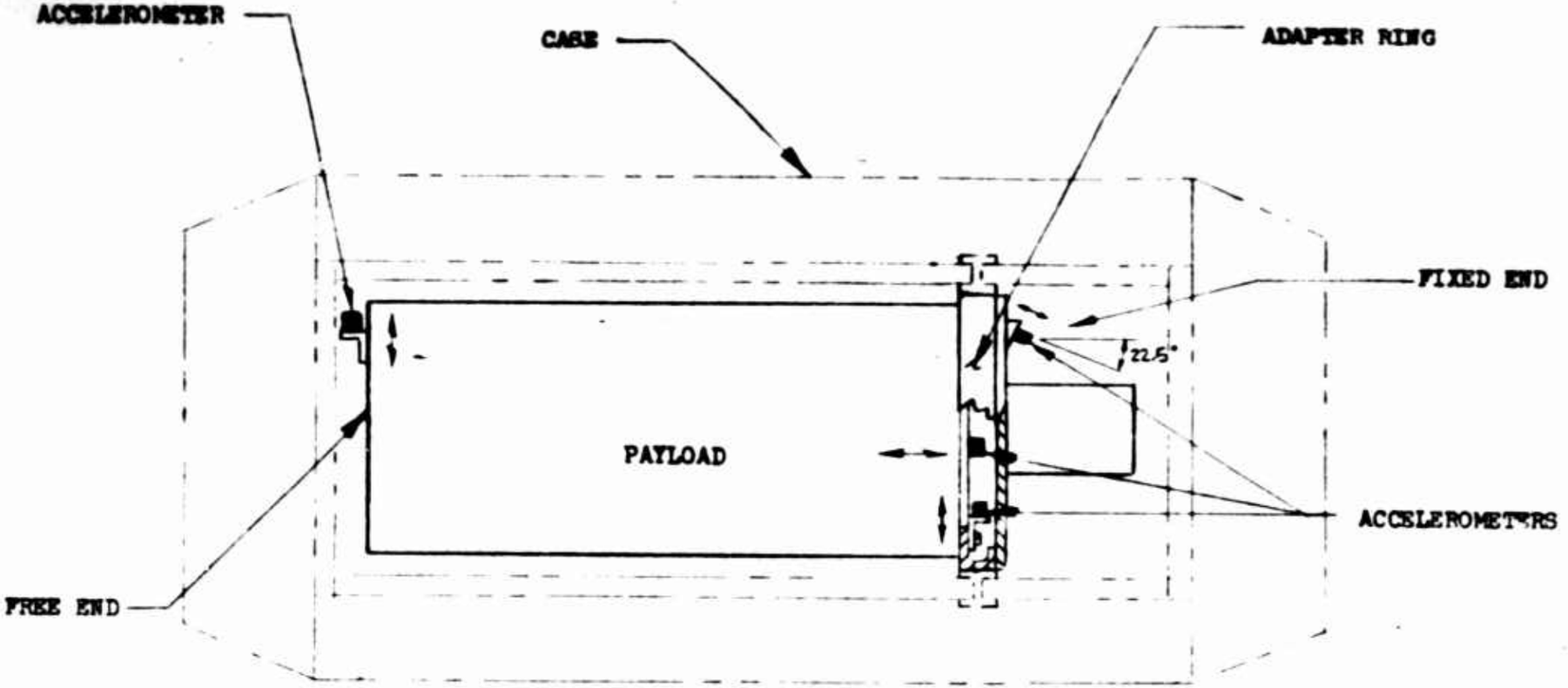

LOCATION OF ACCELEROMETERS (3)
FOR DROP TESTS ON CASES 9 & 10

FIGURE 4

NOT TO SCALE

REF: 6065 8/11/64 F.P.

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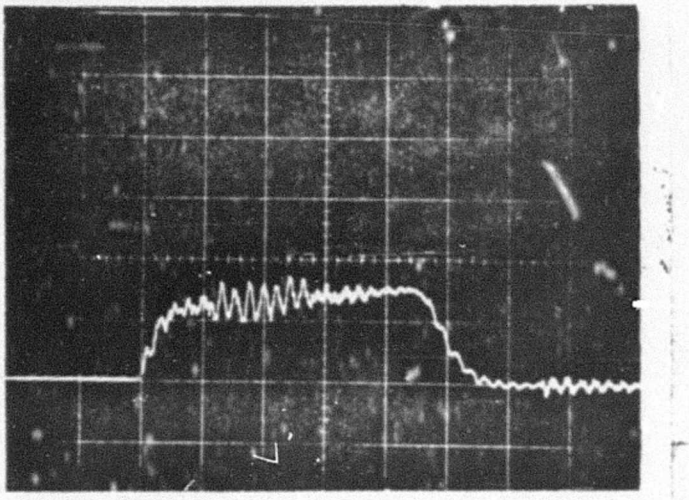


FIGURE 5 , ACCELERATION RESPONSE OF HONEYCOMB RING

Vertical Calibration: 14.6 g's/cm
Horizontal Calibration: 5 msec/cm

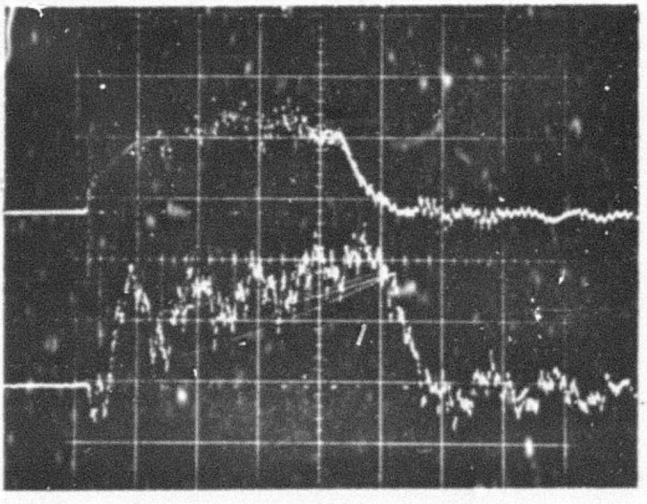
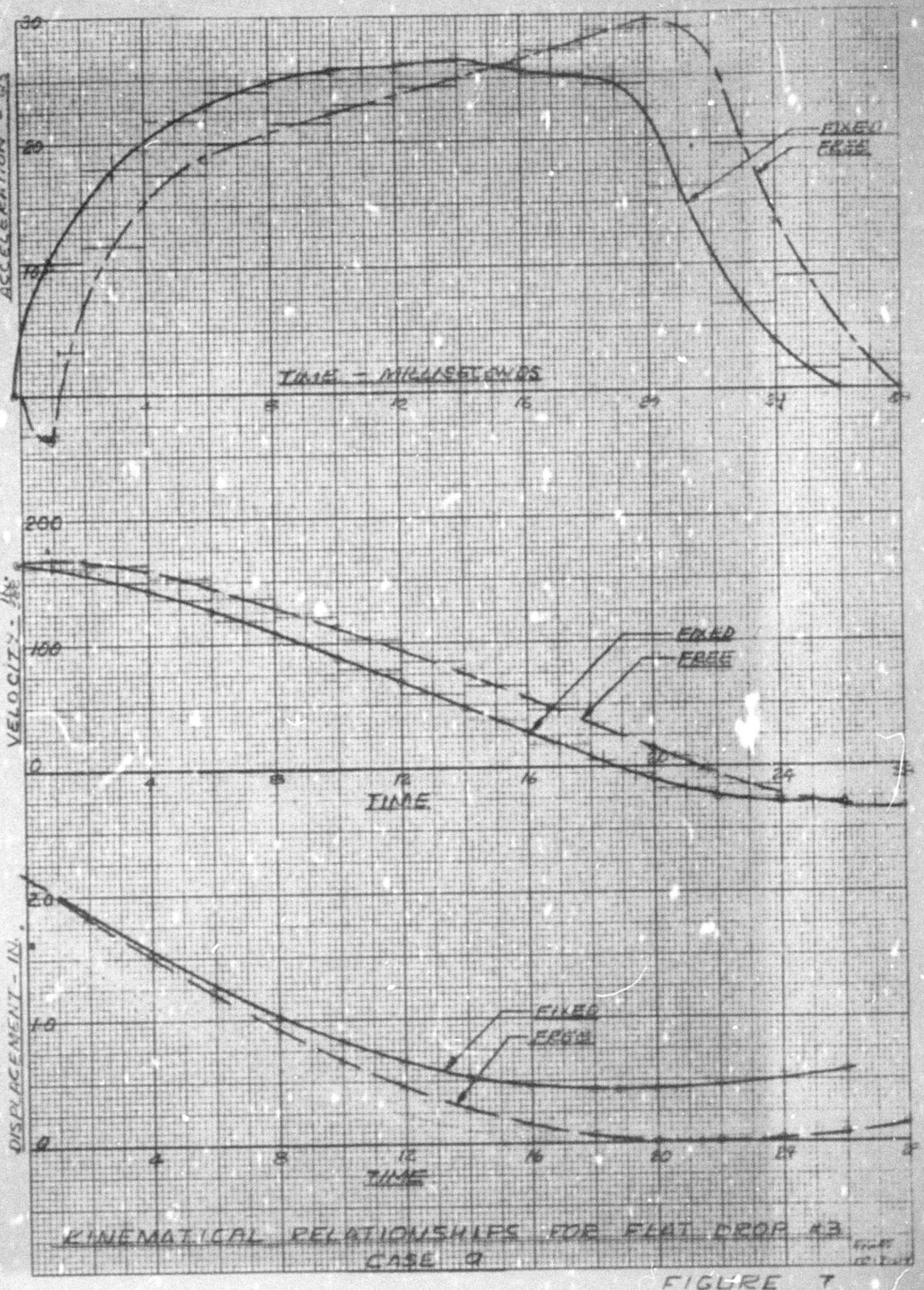


FIGURE 6 , ACCELERATION RESPONSE FOR CASE 9, FLAT DROP 3

Upper Trace: Fixed End of Payload
Calibration - 17.7 g's/cm and 5 msec/cm
Lower Trace: Free End of Payload
Calibration - 14.6 g's/cm and 5 msec/cm



KINEMATICAL RELATIONSHIPS FOR FLAT DROP #3
CASE 9

FIGURE 7

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340R-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH

FORCE – DEFLECTION CURVES

CASE B – GROUP B

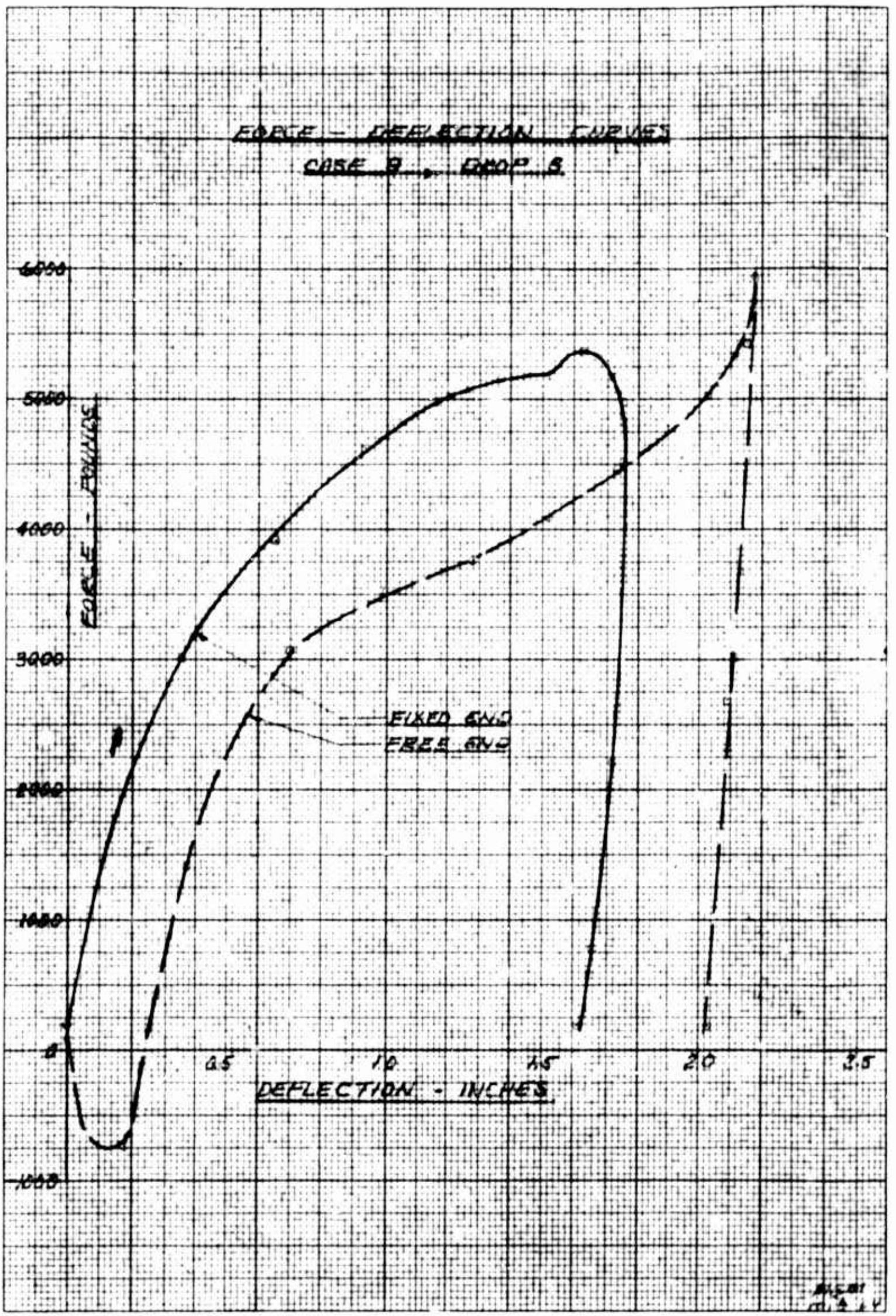


FIGURE 8

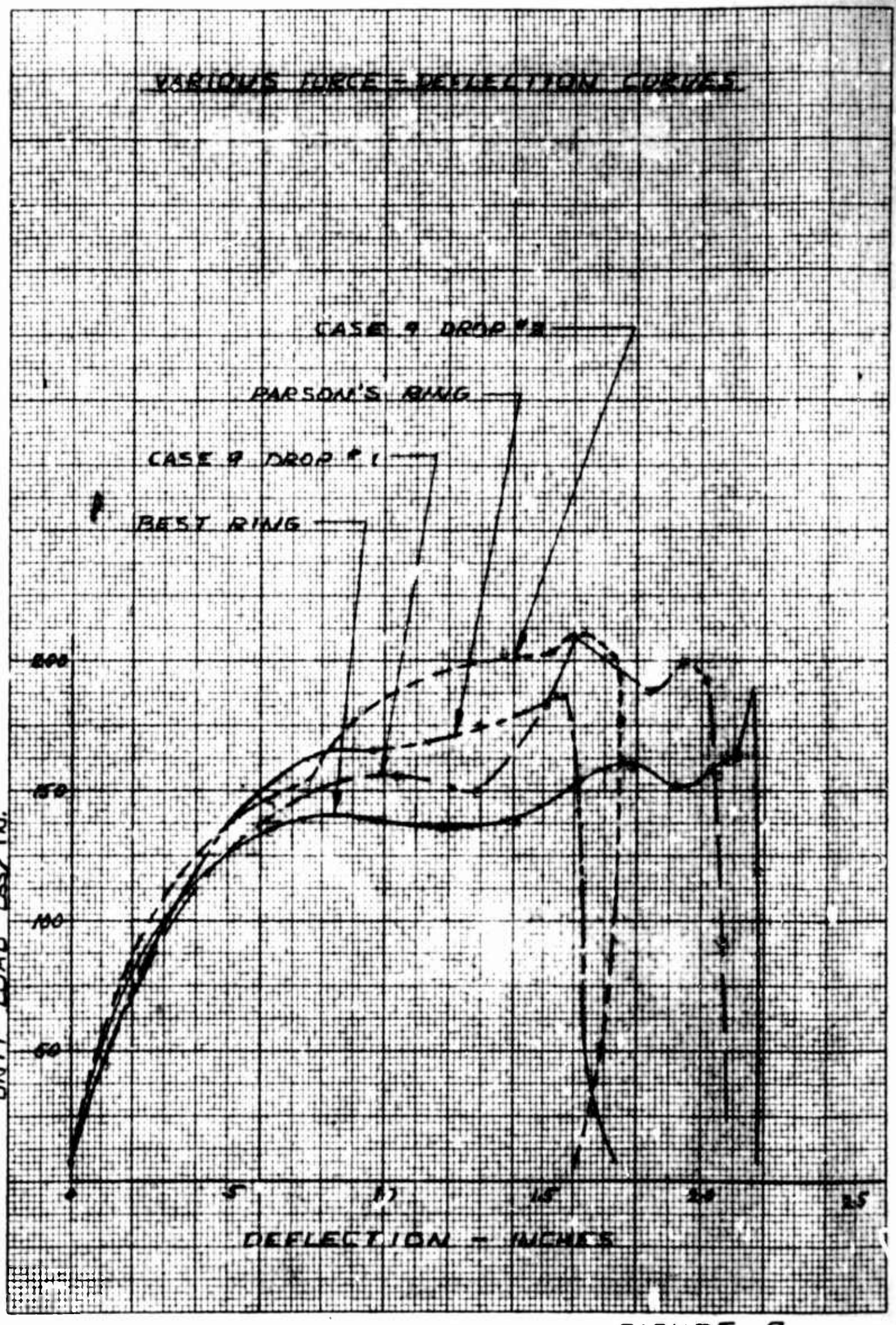

VARIOUS FORCE - DEFLECTION CURVES.
CASE 9 DROP #2
PARSON'S RING
CASE 9 DROP #1
BEST RING
UNIT LOAD LBS/IN.
200
150
100
50
5
10
15
20
25
DEFLECTION - INCHES

FIGURE 9

TABLE 1

RESULTS OF FLAT DROP TESTS - CASE 9

	DROP #1	#2	#3	#4	AVERAGE
FIXED END OF PAYLOAD	MAX. FAIRED CURVE 24.8 / MAX. VALUE 38.9	25.0 / 38.4	26.9 / 39.5	27.3 / 40.2	26.0 / 39.2
FREE END OF PAYLOAD	MAX. FAIRED CURVE 27.7 / MAX. VALUE 36.5	27.7 / 42.3	29.3 / 39.1	28.0 / 37.2	28.2 / 38.8
RATIO OF MAXIMUM VALUE TO MAXIMUM OF FAIRED CURVE	FIXED END 1.57 / FREE END 1.32	1.53 / 1.53	1.47 / 1.33	1.47 / 1.33	1.51 / 1.37

FOR THE FAIRED CURVE, THE AVERAGE VALUE OF PEAK ACCELERATION IS 8% HIGHER AT FREE END THAN AT THE FIXED END.

THE AVERAGE MAXIMUM VALUE IS 1% HIGHER AT THE FIXED END THAN AT THE FREE END.

TABLE 2

RESULTS OF DROP TESTS FOR CASE ~ 10

	FIXED END	FREE END
FLAT DROP * 1	FAIRED VALUE 28.3 g's / MAXIMUM VALUE 44.3 g's	29.5 / 38.7
FLAT DROP * 2	28.5 / 49.7	28.6 / 47.0
FLAT DROP * 3	28.5 / ~ 50	30.0 / 50
FLAT DROPS AVERAGE	28.4 / 48.0	29.4 / 45.2
END DROP * 1	23.8 / 34.8	
END DROP * 2	24.7 / 34.8	
END DROPS AVERAGE	24.2 / 34.8	
EDGE DROP	16.5 / 17.0	

SEE FIGURE 4 FOR LOCATION OF ACCELEROMETERS.

VALUES OF ACCELERATION ARE g UNITS.

ATTACHMENT NO. 1

STATEMENT OF MAN HOURS EXPENDED

SEPTEMBER AND OCTOBER, 1964

	September Man Hours	October Man Hours
Engineering		
Senior Professional	71.0	66.0
Professional	233.0	138.0
Technician		
Drafting, fabrication, and testing	78.5	30.0
Other		
Clerical	18.5	2.0
TOTAL HOURS EXPENDED	401.0	236.0

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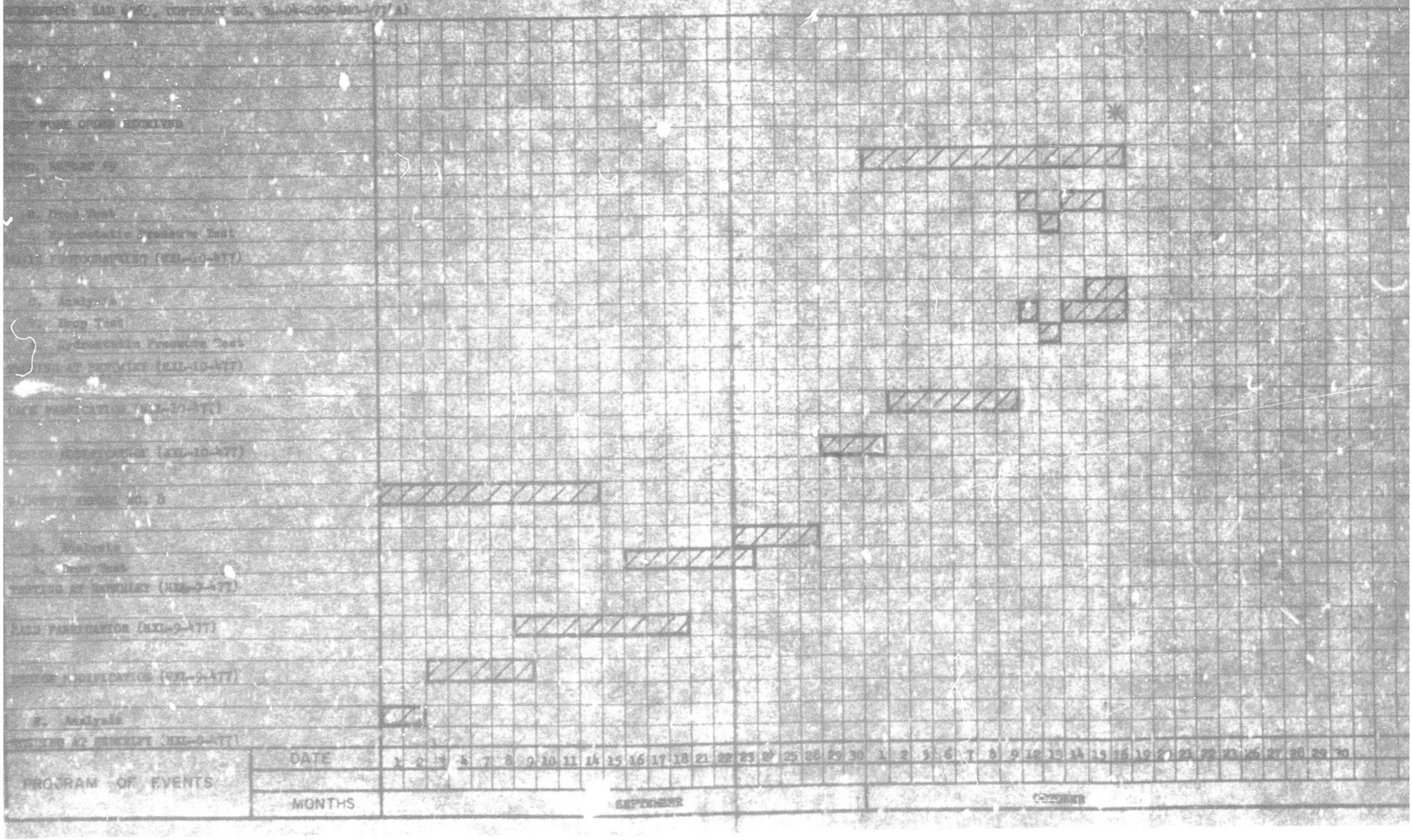

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ATTACHMENT #3
PROGRAM OF ENSUING ACTIVITIES
NOVEMBER & DECEMBER, 1964

REFERENCE: RAD 6065, CONTRACT NO. DA-04-200-AMC-477(A)